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THE JOHNS HOPKINS UNIVERSITY

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Baltimore, Maryland

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~~FINAL REPORT~~,

1 Mar~~ch 19~~62 ~~to~~ 28 Feb~~ruary 19~~63,

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by

Oscar W. Dillon, Jr., ~~Director~~

Submitted to the Air Force Office of
Scientific Research, Washington, D. C.

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PROJECT ACTIVITIES

The research supported by this grant was an investigation of the heat generated as metals (principally aluminum) are deformed in torsion. The major results have been published in the Journal of Applied Physics (Vol. 33, No. 10, p. 3100, October 1962) and the Journal of the Mechanics and Physics of Solids (Vol. 11, p.21, 1963). The information obtained is important because it permits the use of the conservation of energy in the theory of plasticity. The heat that is generated is a source term in the heat conduction equation and couples the mechanical and thermal fields.

Most theoretical studies in thermoelasticity and thermoplasticity do not consider that coupled effects exist and analyze problems as though all the heat is from external sources. In recent years, a few solutions of problems in linear coupled thermoelasticity have been published. The linearized theory is not appropriate for deviatoric (shearing) deformations which are used in the experimental phase of the present research. Therefore, a nonlinear thermoelasticity theory was previously published by us, and a thermoplasticity approach was developed under the present grant. In either case, the solution of boundary-value problems is difficult due to the coupling of nonlinear partial differential equations. This does not detract from the need to consider the coupling phenomenon for a realistic description of metals. It is hoped that the experimental data, obtained in this program, will be of assistance in finding meaningful, approximate solutions. The experimental data on aluminum are in agreement with the postulates of the thermoplasticity postulates.

Temperatures in excess of 500° F were generated in aluminum rods at fifty cycles per second. A technique for the measurement of the detail of the temperature history was developed. This permitted us to show that heat is generated only during parts of the cycle when oscillatory deformations are imposed.

In addition to the thermal information, data on aluminum as an unstable solid has been obtained. A few metallurgists have studied this behavior (Portevin - Le Chatelier effect) in tension, but they have not interpreted it in terms of material instability or examined its effect on the equations of motion. Common practice in solid mechanics simply does not admit that a real material can be unstable. There are at least two important effects that one observes in annealed aluminum which are consistent with the unstable material concept. First, the strain field is nonhomogeneous when it normally would be thought to be uniform. Secondly, very slow waves exist and, therefore, it takes more time than is normally realized to establish equilibrium in an experiment. These data are reported in a paper recently submitted for publication.

It is too early to know which real materials are unstable. However, it is believed the time is at hand to examine unstable materials in every area of solid mechanics (elasticity, plasticity, viscoelasticity). The unstable response has been observed by us in the cases of torsion of tubes and solid bars, and in pure bending of a beam of rectangular cross-section. In addition, other experimental studies at The Johns Hopkins University are not inconsistent with considering this material as unstable. Furthermore, the experimental data obtained under this grant

has been motivation for a theory of "orientable solids" by Professor J. Ericksen. Ericksen's theory is interesting for itself and is possibly a highly significant, new approach in the theory of plasticity.

Requests for reprints of papers have been received from Italy, Japan, Australia, Great Britain and Austria. The Contract Director presented seminars at Princeton University and the University of Pennsylvania on the coupled thermal effects. He also presented a paper on a different subject at the Fourth U. S. Congress of Applied Mechanics at Berkeley, California during June, 1962.

The investigations are being continued by a new OSR Grant. It is believed this research is of considerable fundamental value in establishing realistic constitutive equations that are appropriate for metals at moderately high strains (one percent).

Publications

Two papers were published under this grant.

Dillon, O. W. Jr., "Temperature Generated in Aluminum Rods Undergoing Torsional Oscillations", Journal of Applied Physics, Vol. 33, No. 10, p. 3100, October 1962.

Dillon, O. W. Jr., "Coupled Thermoplasticity", Journal of the Mechanics and Physics of Solids, Vol. 11, p. 21, 1963.

A third paper, "Experimental Data on Aluminum as a Mechanically Unstable Solid", was submitted for publication in February, 1963.

Personnel

Name of Employee	Position
Oscar W. Dillon, Jr.	Director
Joseph Archie	Research Assistant
Chu-Min Fu	Research Assistant
Christy Maltas	Research Assistant
William Dunn	Laboratory Assistant
Harold Walpert	Laboratory Assistant
Jack Lorenz	Laboratory Assistant
John Geoghegan	Laboratory Assistant
Edmund Henneke	Laboratory Assistant
Helen W. Campbell	Secretary

The personnel listed above have been employed part-time on this grant.